PRIMORDIAL MAGNETIC FIELD MEASUREMENTS FROM THE MOON;

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While magnetic field measurements from the Moon play a role in our understanding of the origin of planetary magnetic fields from the solar nebula, these also provide a means for examining experimental limits on several important aspects of observational cosmology. One is the question raised here of measuring primordial magnetic fields left over from the early Universe, an issue which is relevant to large-scale structure formation and Big Bang nucleosynthesis (BBN).

Introduction. The Moon represents a unique vantage point for conducting scientific investigations which are background-limited by the magnetic dipole moment M_e of the Earth and cannot be readily done from Earth, one of which is studying the structure and evolution of magnetic fields in the Universe. What can be measured and determined from the Moon by taking advantage of its small magnetic dipole moment ($<10^{-7}$ M_e [1]) to investigate relics of the early Universe typically involves discussions of cosmic rays, the cosmic microwave background, neutrinos, antimatter, and even dark matter, all representing important subjects in the exploration of space [2]. The conventional Earth-based method of chemical abundances [3,4] derived from our understanding of meteorites, interplanetary dust, comets, and interstellar dust has already

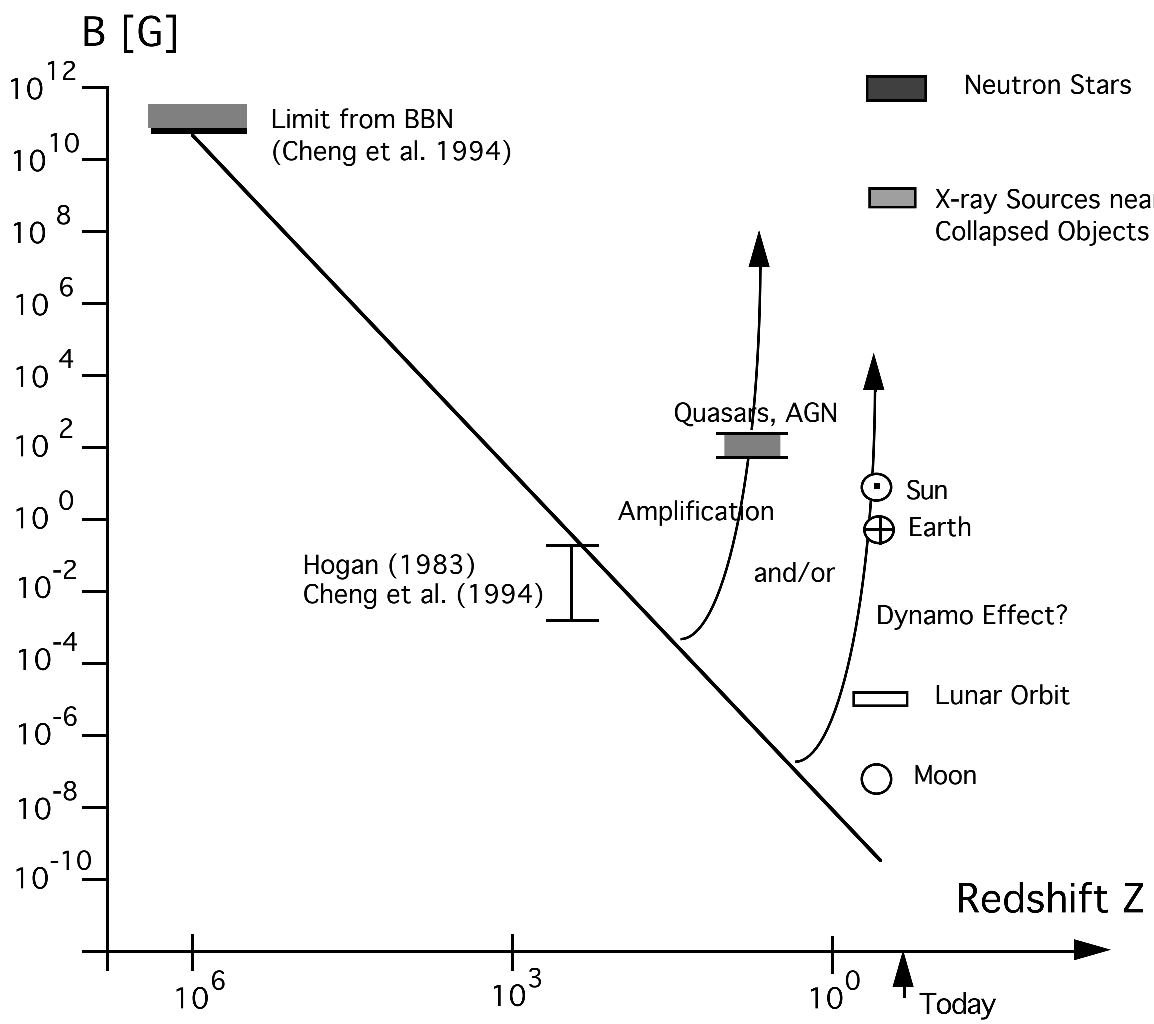

Figure 1

PRIMORDIAL MAGNETIC FIELDS: Blome, H.-J., and Wilson, T.L.

revealed a great deal about the solar system and the nature of the solar nebula. Nevertheless, observational cosmology also places several stringent constraints upon what these conclusions can say regarding the origin of the solar nebula and primordial nucleosynthesis.

Primordial Magnetic Fields. The existence of primordial magnetic fields, their origin [5-8], their significance in Big Bang nucleosynthesis [9], their relationship with inflationary cosmology [10], their detection [11,12], and their direct measurement from the Moon suggested in the present analysis - these features all represent important topics in astrophysics and cosmology. Can we trace back part of the magnetic field in the (proto-)solar system to a cosmological magnetic field, analogous to our effort in disentangling primordial and stellar-produced elemental abundances? This question is illustrated in Figure 1. The diagonal line shows the variation of a hypothetical primordial magnetic field B under the assumption of flux conservation in an expanding universe,

$$B = B_i \left(\frac{R_i}{R} \right)^2 = \left(\frac{1+z}{1+z_i} \right)^2 = B_i \left(\frac{\rho_i}{\rho} \right)^2 , \qquad (1)$$

where B_i represents an initial (primordial) magnetic field at time t_i or redshift z_i. The proposal is to use the Moon as a "wake-shield" from the interplanetary solar wind, trying to take advantage of the plasma void on its downwind, leeward side. Earth-based experiments, by comparison, are severely background-limited by the Earth's magnetic dipole moment, giving it a surface field of 0.62 G(gauss), while the Moon has surface fields on the order of γ's ($1\gamma = 10^{-5}$ Gauss) when it is outside the Earth's magnetospheric tail. This places it much closer (four-seven orders of magni-tude) to the conserved flux line (1), Figure 1, than is an Earth-based observer, an advantage which has not been pointed out before. The argument is similar to that regarding proton decay [2].

The magnetic field intensity in the wake of the Moon has been studied [13,14]. Because the total pressure outside (gas plus magnetic) the wake must equal the pressure inside (magnetic only), the field B can be slightly enhanced. Nevertheless, the true vacuum in the wake (zero gas pressure) represents several advantages, and this "wake-shield" feature is the question of interest.

Conclusions. Observations from the Moon and the Earth-Moon system in the next century will improve our knowledge of the Universe and probably open several new windows to the very early period of its formation. Measurements of primordial magnetic fields will help us probe the post-recombination era of cosmology. This, in turn, will extend and refine our picture of the origin of the Universe, a prospect particularly suited for the vantage point of the Moon as a scientific laboratory [15]. Primordial magnetic field measurements will necessarily provide important information about the physical processes which contributed to the origin of the solar system, and take our understanding beyond what we believe today.

References

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